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Particle production at RHIC energies

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Abstract.
This paper presents recent results from the BRAHMS experiment at RHIC; including results on particle production in rapidity space extending from y=0 to $y \sim 3$ and on the transverse momentum distribution of fully identified charged particles. These results were obtained from the 5% most central Au-Au collisions recorded during RHIC Run-2 at $\sqrt{s_{NN}} = 200$ GeV.

INTRODUCTION

BRAHMS is the only RHIC experiment that is able to study fully identified particle production and energy flow over a wide range of rapidity (from y=0 to y=4 for pions). This coverage, which almost reaches the fragmentation regions, is ideal for studies of the bulk properties of the system formed in heavy ion collisions at RHIC energies. This work reports recent results obtained from the analysis of data collected with the BRAHMS spectrometers in Au-Au collisions at $\sqrt{s_{NN}} = 200$ GeV. A detailed description of the BRAHMS experimental setup can be found in [1]. All results shown here are preliminary and were obtained from a sample of the 5% most central events.

PARTICLE PRODUCTION

Momentum distributions of fully identified charged particles were obtained with conventional magnetic spectrometers instrumented with state-of-the-art time-of-flight and ring imaging and threshold Čerenkov detectors. For each particle type, the density in rapidity space is obtained by integration over the p_{T} dependence of these distributions. With the distributions dropping rapidly as p_{T} increases, a good fraction of the integral comes from unmeasured yields at low p_{T} . An extrapolation is thus necessary to cover the unmeasured regions. Empirically the pion yields were found to be best fitted by a power law, the kaon distributions by a single exponential in p_T, and the proton distributions with a single exponential in m_T.

The resulting rapidity density distributions are shown in panels a and b of figure 1. Panel a shows the densities for all charged particles. Because pions dominate this figure, panel b expands the view for the kaon, proton and antiproton distributions.

A remarkable feature of these distributions is their common bell shape character. (Pions, kaons and anti-proton distributions are fitted well with double Gaussians). This observation has a possible explanation based on the postulate that particle production in the momentum range measured in the present experiment is driven primarily by the distribution of partons in the colliding ions. As the energy of the collisions increases, the

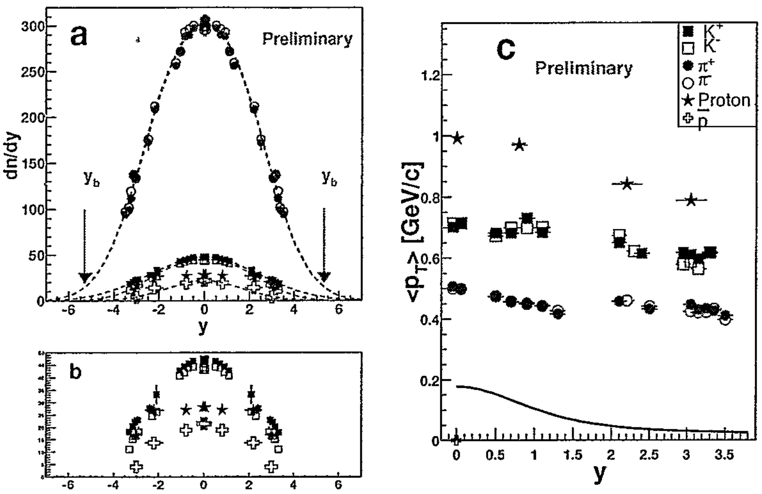

FIGURE 1. a) and b)Symmetrized rapidity density distributions for identified charged particles measured in the 5% most central events. The measurements were done for y>0. c) Mean ransverse momentum as function of rapidity

parton distributions can be resolved to smaller values of x (fraction of the total momentum of the hadron). The convolution of the left and right moving parton distributions leads to an initial bell-shaped dn/dy distribution for produced particles in symmetric system centered around y=0.

This distribution may evolve in later stages through secondary interactions, but it retains its bell shape. In this picture there is neither a wide plateau connecting the two fragmentation regions, as Feynman's intuition had it [2], nor an extended boost invariant longitudinal expansion, as proposed by Bjorken [3].

A good summary of all the p_T distributions extracted in this analysis is shown in panel c of figure 1; the average transverse momentum with which the detected particles are produced at different rapidities. Worth noting in this result is the small change of the pion and kaon average p_T as function of y. For comparison, a calculated average p_T for pions is also drawn in panel c. The curve was obtained with a single thermal source described by a Boltzmann distribution with a temperature of 200 MeV.

An inspection of the transverse momentum distributions shows that for the more massive particles there is a very clear curvature in the spectra as the value of p_T approaches zero (see Figure 2). This observation, together with the almost exponential shape of the distributions at higher p_T and for lower mass particles, is well reproduced by a functional form based on a thermalized system expanding radially [4].

After integration over y and azimuthal angle and assuming that a Boltzmann distribution describes the system, the following functional form is obtained, and is used to fit the spectra:

$$\frac{dn}{m_T dm_T} = Am_T \int_0^R rdrK_1\left(\frac{m_T cosh\rho}{T}\right)I_0\left(\frac{p_T sinh\rho}{T}\right)$$

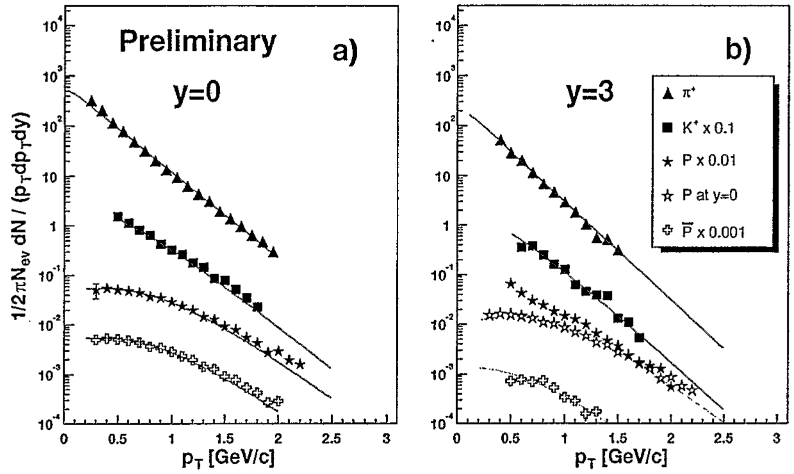

FIGURE 2. "Blast wave" fits to pions, kaons and protons at rapidity y=0 (panel a) and y=3 (panel b)

TABLE 1. Results of blast wave fits

Rapidity	Temperature [MeV]	Velocity
0	127 ± 2	0.57 ± 0.01
0.7	112 ± 1	0.60 ± 0.01
2.2	128 ± 3	0.50 ± 0.01
3	136 ± 4	0.44 ± 0.02

where $\beta_T = tanh\rho$ is the transverse velocity of the flow in units of c, and T is the decoupling temperature.

Several functions that describe the radial dependence of the flow velocity have been proposed. Here the simplest assumption of a transverse flow velocity that is constant at all radii is assumed. This choice may not be fully adequate, but does serve to highlight the rapidity dependence of the flow velocity. The table 1 summarizes the results.

The shapes of the distributions are well reproduced by the fits, with a 30 % reduction in transverse velocity found going from y-0 to y=3. This reduction is also suggested by the different shape of the mid-rapidity proton distributions as compared to that at the most forward rapidity, as shown in Fig. 2b where the y=0 points have been shifted down to facilitate the comparison.

The measured net proton at mid-rapidity [6],[7] was an early subject of much discussion in the community because it went against an expected baryon free region around $y \sim 0$; the energy of the colliding beams was so high that the initial baryon number should end up in the fragmentation regions if tied to the valence quarks . But the first results extracted at y=0 indicated otherwise, the net-proton number was not equal to zero. Some mechanism was transporting baryon number to mid-rapidity. D. Kharzeev [5] had predicted that the x distributions of gluons of the initial baryon extend to very small values of x. At the time of the collision these distributions would overlap and after "dressing" with quarks from the sea the low-x gluons of the initial baryons bring in

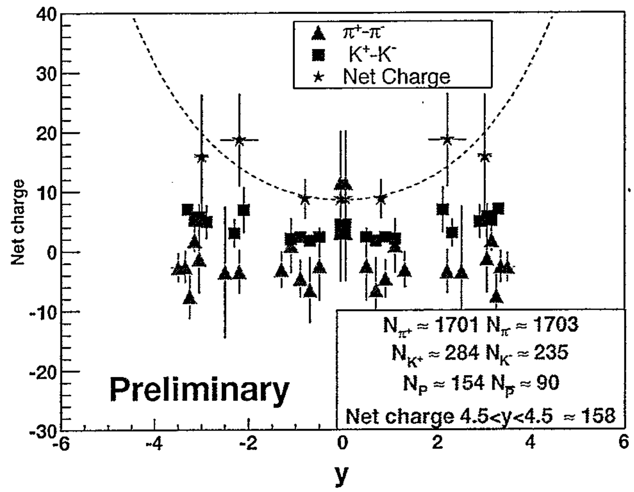

FIGURE 3. Net charge as function of rapidity (star symbols). The difference $K^+ - K^-$ is shown with squares, and the triangles show the difference $\pi^+ - \pi^-$. The dashed line is the fit to the function refered in the text.

effect net baryon number to mid-rapidity. This effect would have a rapidity dependence as $\frac{Zb}{sinh(y_{max}b)}cosh(yb)$ where Z is the charge of the ions, and b is related to nature of the system that brings baryon number to mid-rapidity and predicted to be close to 1/2. The parameter y_{max} is set to be equal to 4.5. Figure 3 shows the net charge measured up to rapidity 3 and a fit to the function mentioned above, The fit parameters are $b = 0.49 \pm 0.10$ with $\chi^2 = 1./7$.

SUMMARY

Analysis of the most central data sample collected during RHIC Run-2 (Au-Au at $\sqrt{s_{NN}} = 200$ GeV) is consistent with a thermalized system with a decoupling temperature around 120 MeV, and a strong radial flow $\beta_T \sim 0.6$ that diminishes by as much as 30% at the most forward rapidity measured.

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